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Summary: Spin Physics

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Abstract: The spin physics parallel sessions at this workshop made a critical review of the physics potential of future experiments on polarized nucleons, with an emphasis on the potential impact of polarized electron-proton collisions at HERA. A summary of the results and discussions from these sessions is presented in this article.

1 Introduction

A series of polarized lepton-nucleon scattering experiments at CERN, SLAC and DESY has considerably improved our knowledge on the spin structure of the nucleon over the past few years. These experiments were however largely restricted to the inclusive structure function $g_1(x,Q^2)$, probing a particular combination of quark polarizations in the nucleon. As a consequence, our picture of the nucleon spin structure is still far from complete. Several future experiments are now attempting to resolve remaining open issues. The spin physics sessions of this workshop made a critical review of the physics potential of these future experiments, with particular emphasis on the potential impact of polarized electron-proton collisions at HERA.

With several new and ongoing spin experiments, much information on the proton spin structure will become available in the next few years: complementary measurements at HERMES, COMPASS and RHIC will yield first information on the gluon contribution to the proton spin, combining future results from these experiments with existing structure function data, it will moreover be possible to separate quark and antiquark contributions to the proton spin and to carry out a flavour decomposition. These experiments, as well as future measurements at Jefferson Laboratory will also give first insight into potential higher twist contributions to the proton spin. The kinematical scope of these experiments is however limited, and they will still leave many questions unanswered.

Given the numerous new insights HERA has provided into the unpolarized proton structure in the past, the option of polarizing its beams to study proton spin structure appears very tempting. Polarization of the HERA electron beam comes naturally due to the Sokolov-Ternov effect, and is already used for the HERMES experiment. Polarizing the proton beam is a much more complicated task, and other sessions of this workshop were devoted to the machine aspects connected with this project. The physics prospects of a polarized HERA collider were investigated for the first time in a working group of the 1995/96 "Future Physics at HERA" workshop [1]. The most important observables identified in this working group were the polarized structure function $g_1(x,Q^2)$, polarized weak structure functions, dijet production in polarized DIS and polarized photoproduction of jets. The working group established the measurability of all these observables, given an integrated luminosity of at least 200 pb^{-1}. Encouraged by these results, a follow-on workshop "Physics with Polarized Protons at HERA" was organized in 1997 [2, 3], where more elaborate studies of the measurability of different aspects of the proton spin structure at HERA were carried out. For present workshop, many of these analyses have been further refined, and a number of new processes, like deeply virtual compton scattering or spin asymmetries in diffraction and in leptoquark production, have been investigated in detail for the first time. A new aspect to spin physics at HERA is also the possibility of colliding the HERA proton beam with the polarized electron beam of a linear electron-positron collider, whose construction is currently considered at DESY. Several studies at this workshop have illustrated the physics prospects of this project.

2 Current and future experiments

The HERMES collaboration is operating a polarized fixed target spectrometer with final state hadron identification in the HERA electron beam. In addition to measurements of individual polarized quark distributions from semi-inclusive asymmetries [4], this experiment has recently provided a first glimpse on the polarized gluon distribution [5] by studying charged hadron production at high transverse momentum [6]. In the near future, HERMES will study a variety of inclusive and semi-inclusive observables in polarized electron-nucleon scattering. In particular the semi-inclusive measurements at HERMES will yield new information on angular lepton-hadron correlations [7] and on transverse momentum dependence (Collins effect) in fragmentation processes [8, 9].

Running at lower electron energy than HERMES, the polarized deep inelastic scattering programme at Jefferson Laboratory [10] is aiming to study spin structure functions at large x and/or low Q^2. This kinematic region is of particular interest for the determination of higher twist contributions to polarized structure functions, testing integral relations [11], lattice calculations [12] and bounds on asymmetries [13].

The COMPASS experiment [14], which is currently under construction at CERN, will start measuring inclusive and semi-inclusive observables in polarized lepton-nucleon scattering next year. With a lepton beam energy significantly above HERMES, the COMPASS experiment will be able to use charm production as a probe of the polarized gluon distribution. COMPASS will also carry out a broad programme of inclusive as well as semi-inclusive measurements on longitudinally and transversely polarized targets.

A new domain for spin physics will open up with the commissioning of the Relativistic Heavy Ion Collider (RHIC) at BNL two years from now. RHIC can be operated with polarized proton beams, allowing to study polarized proton-proton collisions at $\sqrt{s} = 200 \ldots 500$ GeV with two multi-purpose collider detectors. The RHIC spin physics programme [15] covers a wide variety of processes probing different aspects of the nucleon spin structure; first detailed simulations [16] are now ongoing and have been reported to the workshop. Polarized quark distributions for individual flavours can be accessed at RHIC from massive gauge boson production, simulations indicate that this measurement should be relatively unproblematic [15]. The polarized gluon distribution could be measured at RHIC from prompt photon or jet production, both channels are however not free from experimental as well as theoretical problems. In particular the direct photon channel has been subject of detailed simulation [17], demonstrating the experimental feasibility of measuring this observable. The theoretical interpretation of direct photon data is however problematic already in the unpolarized case, since the experimental isolation cuts, which are applied to define the photon, can hardly be matched in the theoretical calculation. The extraction of the gluon distribution from these data is therefore not free from ambiguities, direct photon data are therefore no longer used in unpolarized fits. The problem of photon isolation will be the same in polarized studies, thus casting doubt on the reliability of this measurement. Alternative photon isolation criteria [18, 19] could allow a better matching of experiment and theory. Using the isolated photon definition proposed in [19], a first case study for RHIC was carried out recently [20]. Jet production at RHIC as a probe of the polarized gluon distribution has not yet been investigated in great detail, this process has the advantage of having large production rates, but suffers from the numerous competing partonic subprocesses.

Data from HERMES, Jefferson Laboratory, COMPASS and RHIC will largely extend our knowledge on several aspects of the nucleon spin structure over the next few years. These measurements are however limited in their kinematical reach, and they will still leave many questions unanswered. All three polarized lepton-nucleon scattering experiments are working on fixed targets, and are therefore not able to access the behaviour of polarized structure functions at small x. Also, photoproduction at these experiments will largely be dominated by direct photon-nucleon interactions, thus not allowing studies of the spin structure of the photon. Measurements at the RHIC collider will also cover only the behaviour of the polarized parton distributions at large and medium x, which might in particular be problematic for an accurate determination of the first moment of the polarized gluon distribution. In unpolarized proton structure, similar aspects are of high interest, and could first be studied experimentally at the HERA electron-proton collider.

3 Prospects of Spin Physics at HERA

The operation of HERA with polarized proton and electron beams would allow to study a wide variety of observables in polarized electron–proton collisions at $\sqrt{s} = 300$ GeV. The physics prospects of this project were first studied in a working group of the 1995/96 workshop "Future Physics at HERA" [1] and a follow-on workshop "Physics with Polarized Protons at HERA" [2, 3] in 1997. These workshops identified a number of key observables, which allow to probe several aspects of the proton and photon spin structure inaccessible at other experiments. These encouraging physics prospects also triggered much effort on machine studies for operating HERA with a polarized proton beam. At the present workshop, latest developments on machine aspects [21] and physics prospects were shown. Concerning the physics studies, much effort has gone into optimization and refinement of the measurement of key observables as well as into studies of potential new channels. The most prominent new results are summarized in the following.

3.1 Spin Physics at small x and large Q^2

The unpolarized electron-proton programme at HERA has extended the kinematical domain of deep inelastic scattering towards small values of the Bjorken scaling variable x and large values of the invariant momentum transfer Q^2. Both limits probe the structure of the proton and the dynamics of QCD interactions at a previously unexplored level and give rise to a multitude of

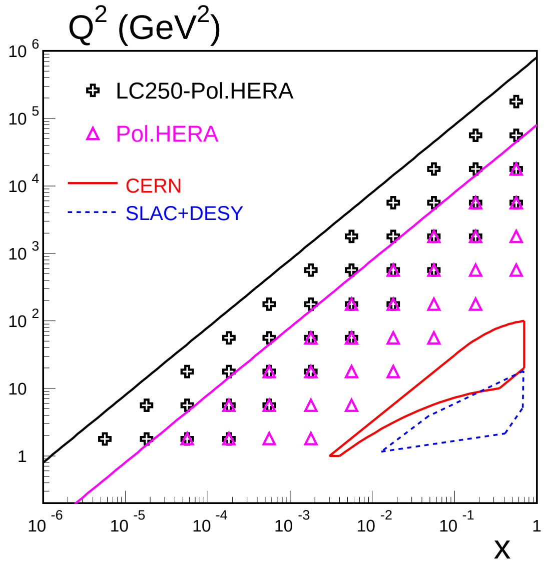


Figure 1: Kinematical region accessible with linear collider electron beam on HERA proton beam, compared to kinematics of present experiments and HERA.

new phenomena, which have been studied in detail by the two HERA collider experiments over the past years.

The kinematical reach of HERA towards large Q^2 allows perturbative QCD evolution of structure functions to be tested over a long range in Q^2, thus allowing for example for an indirect determination of the unpolarized gluon distribution from $F_2(x, Q^2)$. Likewise, operation of HERA with polarized protons would allow measurements of $g_1(x, Q^2)$ well beyond the kinematical reach of present fixed target experiments, thus providing important constraints to QCD fits and allowing for an indirect extraction of the polarized gluon distribution from QCD evolution of $g_1(x, Q^2)$. The prospects of this measurement have been investigated in detail already at previous workshops [1, 2, 22], some updates have now made. Concerning detector effects on the extraction of $g_1(x, Q^2)$ from the measured asymmetry, new studies of uncertainties induced by bin migration have been carried out [23], showing in particular that bin migration effects can be reduced by using the hadron method for the reconstruction of the event kinematics.

To study the impact of HERA structure function data on a determination of polarized parton distributions from QCD fits, projected HERA data points have been included in global fits [22]. A recent improvement to these studies is the inclusion of projected charged current data, which will allow for a more precise determination of the quark contribution to the proton spin [24].

A new aspect to measurements of $g_1(x, Q^2)$ at HERA would be the possibility of colliding the HERA proton beam with the electron beam of a future linear collider, whose construction is currently considered at DESY. First studies on the kinematical reach of the option were presented [25]. Already a linear collider with electron beam energy of 250 GeV would enlarge the kinematical reach of HERA by about an order of magnitude towards large Q^2 and small x, see Fig. 1.

The behaviour of polarized structure functions at small x is currently not known from experiment. Present $g_1(x, Q^2)$ data from the SMC collaboration [26] reach down to $x = 0.0008$,

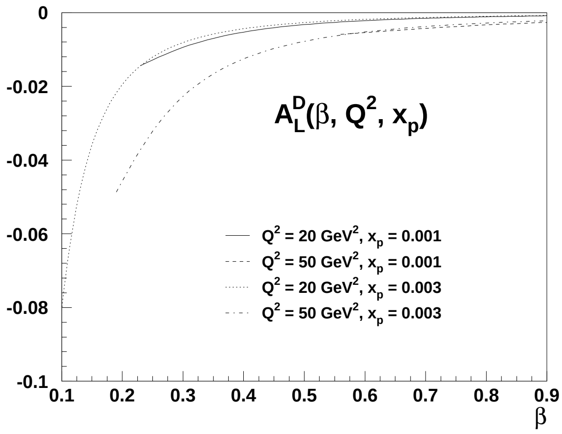


Figure 2: Expected perturbative spin asymmetry in diffractive deep inelastic scattering at HERA in the leading ln Q^2 approximation.

corresponding however to very small values of $Q^2 = 0.2$ GeV^2. The SMC data have motivated several attempts of a theoretical interpretation [27, 28], which are however yet inconclusive.

In the small-x domain, one would ultimately expect the ln Q^2 resummation of QCD to break down, since terms proportional to ln x should become of equal importance, thus requiring a reordering of the perturbative series. HERA measurements of the unpolarized structure function $F_2(x, Q^2)$ at small x are however still consistent with the DGLAP evolution equations, based on ln Q^2 resummation. In this structure function, one finds the most singular terms at small x to be of the form $\alpha_s^n \ln^n x$. In the polarized structure function $g_1(x, Q^2)$, even more singular terms of the form $\alpha_s^n \ln^{2n} x$ are present [29], resulting in a stronger enhancement at small x. At this workshop, a first attempt has been presented [30] to combine small-x resummation with the usual DGLAP evolution into a unified evolution equation. As a result, one observes a significant enhancement of the magnitude of g_1 at small x, compared to DGLAP evolution only. A similar enhancement is also expected in $g_2(x, Q^2)$ at small x [31]; a measurement of this structure function seems however to be unlikely at HERA.

About 10% of unpolarized deep inelastic scattering events at HERA yield a final state containing a diffractively scattered proton surrounded by a large rapidity gap. Since its first observation at HERA several years ago, diffraction in deep inelastic scattering has triggered a lot of theoretical effort towards its understanding. At present, it is still fair to say that an unambiguous interpretation of this phenomenon could not yet be achieved, since both perturbative as well as non-perturbative effects are expected to contribute with comparable magnitude. Theoretical studies on diffraction in polarized deep inelastic scattering were presented at this workshop. Estimations of non-perturbative contributions based on regge theory [32] predict a diffractive asymmetry not exceeding 10^{-4}, while perturbative diffractive exchanges [33] give rise to asymmetries of the order 10^{-2}, as can been seen in Fig. 2. The ratio of perturbative to non-perturbative contributions to diffraction appears therefore to be more favourable in the polarized than in the unpolarized case, in particular due to terms of the form $\alpha_s^n \ln^{2n} x$, which are present only in the polarized, but not in the unpolarized diffractive amplitude. Studies of particular final states in polarized diffractive scattering are also ongoing, large asymmetries are predicted [34] for example in diffractive charm production.

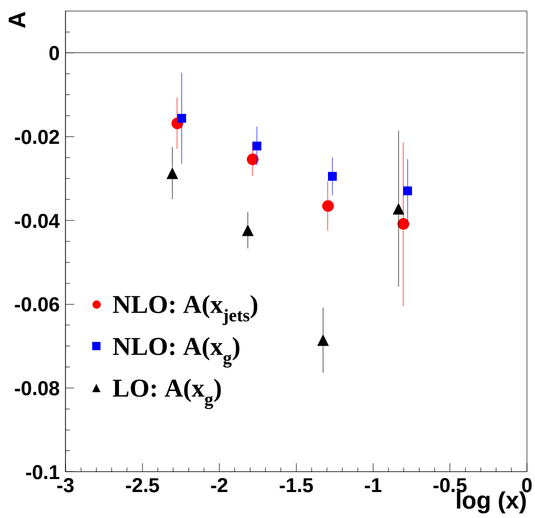


Figure 3: Expected spin asymmetry in deep inelastic jet production. Cuts according to [36]. Errors correspond to integrated luminosity of 200 pb^{-1} and 70% polarization of electron and proton beams.

3.2 Jet production in deep inelastic scattering

The most promising direct probe of the polarized gluon distribution $\Delta g(x, Q^2)$ at HERA is the measurement of asymmetries in dijet production in polarized deep inelastic scattering. Already the past workshops have proven [35] that this observable allows for a determination of $\Delta g(x, Q^2)$ down to $x = 0.003$, almost an order of magnitude in x below the reach of measurements at RHIC. Since current QCD fits predict an important contribution to the first moment of $\Delta g(x, Q^2)$ from this region, this measurement appears to mandatory for a determination of the gluon contribution to the proton spin.

Earlier analyses of dijet production in polarized deep inelastic scattering have now been extended considerably [36] with the incorporation of next-to-leading order corrections to the parton level subprocesses [37]. It could be shown that the gluon induced scattering process remains dominant source of dijet events also at NLO. Moreover, the non-trivial correlation between the proton energy fraction x_g of the gluon contributing to the scattering process and the reconstructed x_{jets} from the final state is now understood at NLO, thus allowing for a consistent extraction of the polarized gluon distribution at this order. The expected jet production asymmetry at next-to-leading order is displayed in Fig. 3.

The impact of dijet data on QCD fits of polarized parton distributions has been investigated in detail [22, 24]. It could be shown that these data are in particular essential to constrain the shape of the gluon distribution.

The kinematical reach of the dijet measurement would also be extended by almost another order of magnitude in x for the option of colliding the electron beam from a linear collider with the HERA proton beam [25].

As an alternative to the dijet measurement, it has been suggested to use current-target correlations to determine the polarized gluon distribution [38]. This process has the advantage that no requirement on jets in the final state is made, thus including all inclusive deep inelastic scattering events in the analysis. The extraction of $\Delta g(x, Q^2)$ from this process is however far less clean than from the dijet measurement, large systematic uncertainties must be expected.

Jet production in the forward proton region has been suggested as a probe of QCD enhancement effects at small x in the unpolarized case. Measurements of this observable turned out to be substantially above the expectations obtained by resumming only $\ln Q^2$ terms, thus indicating the presence of large $\ln x$ in this process. First studies of small-x resummation effects in polarized forward jet production were presented at the workshop [39], indicating that small-x resummation results in a characteristic increase of the cross section for this observable, which could therefore be used as a tool to study small-x dynamics in polarized scattering.

3.3 Polarized Photoproduction

Cross sections in electron-proton collisions become largest, if the virtuality of the photon mediating the interaction is small. In this photoproduction limit, one can approximate the electron-proton cross section as a product of a photon flux factor and an interaction cross section of a real photon with the proton. Many unpolarized photoproduction reactions are presently measured at HERA, and their study has continuously improved our knowledge on proton and photon structure as well as our understanding of the transition between real and virtual photons over the last years.

Polarized photoproduction processes have already been in the focus of the past two workshops [40], where jet photoproduction was identified as the most promising channel for a determination of both the polarized gluon distribution in the proton and the polarized parton distributions in the photon. Jet production in the photon direction originates mainly from photon-gluon fusion processes, and thus reflects the gluon polarization in the proton. The situation is more involved in the proton direction, where most events are induced by the yet unknown resolved partonic content of the polarized photon. Given the polarized parton distributions in the proton to be known from other sources, jet photoproduction in the proton direction can be used to determine the polarized parton distributions in the resolved photon. Next-to-leading order QCD corrections to polarized photoproduction of jets have recently been calculated [41], resulting in larger perturbative stability of the predictions and enabling a consistent extraction of parton distributions at this order.

Knowledge on parton distributions in the polarized photon is essential to exploit the full physics potential of electron-photon and photon-photon collisions at a future linear electron-positron collider, which is foreseen to operate with polarized beams. At present, it seems that polarized photoproduction of dijets at HERA is the unique process to determine these distributions. Given that jet production originates from several different partonic subprocesses, unfolding of all polarized quark and gluon distributions in the photon from dijet measurements is a very involved, if not impossible task. In the unpolarized case, one successfully applies the so-called effective parton approximation [42]. In this approximation, one replaces the sum over different partonic subprocesses, each weighted with a different parton distribution, by one universal subprocess, weighted with an effective distribution. This effective distribution is a linear combination of parton distributions, where each distribution is weighted with the approximate importance of the corresponding subprocess. This approximation has now been extended to the polarized case [43], where it will help to quantify the expected precision of a polarized photon structure measurement at HERA.

Polarized photoproduction of charmed quarks has been discarded as competitive probe of the polarized gluon distribution already at previous workshops [40] due to the expected low charm tagging efficiency. The production of open charm and of bound states of charmed quarks has however received renewed interest at this workshop as testing ground for models for charm production [44] and charm fragmentation [45].

3.4 Deeply virtual compton scattering

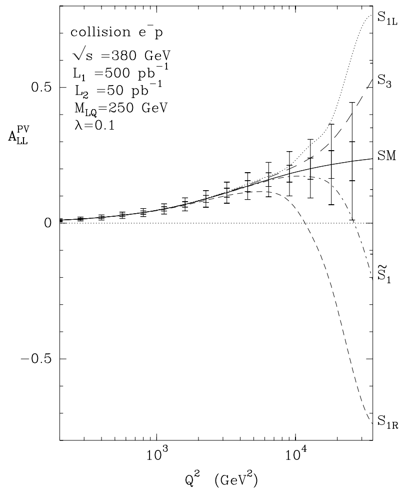
The exclusive process $\gamma^* p \to \gamma p$ (deeply virtual compton scattering, DVCS) can be used to probe aspects of the proton structure beyond the observables usually studied in inclusive and semi-inclusive deep inelastic scattering [46]. It particular, this reaction allows a measurement of non-forward (skewed) parton distributions, which are universal quantities expected to arise in diffractive and exclusive scattering processes. A direct measurement of the cross section for DVCS is however not possible at HERA, since this process is concealed by a large background from photon bremsstrahlung in ordinary electron-proton scattering. By measuring single spin asymmetries in exclusive photon production in the scattering of polarized electrons off unpolarized protons, it is however possible to access the interference term of the DVCS amplitude with the DIS amplitude. First numerical studies of this process have been presented at the workshop [47]. These are indicating large single spin asymmetries, which will allow a determination of skewed parton distributions at HERA, once both collider experiments are operating with longitudinal electron polarization. Adding proton polarization would enable a measurement of polarized skewed parton distributions as well.

3.5 Searches for new phenomena

If the upcoming high luminosity runs at HERA show some evidence for deviations from the Standard Model, polarization of the proton beam could help to determine the origin of this deviation. A case study on new physics at polarized HERA for leptoquark production has been reported at this workshop [48]. Leptoquarks are objects carrying both lepton and quark quantum numbers, they can be created in lepton-quark scattering and would show us as peaks in the x-distribution of deep inelastic scattering events. According to their quantum numbers and their coupling structure to leptons and quarks, leptoquarks can be classified into different species [49]. HERA could in principle detect leptoquarks with a mass up to almost its electron-proton centre-of-mass energy. This detection is already possible in unpolarized scattering. However, based on information from unpolarized scattering only, it will turn out to be very hard to determine the species of the observed leptoquark. In [48], it was demonstrated that polarization asymmetries in leptoquark production can be used extract the precise coupling structure of an observed leptoquark, and thus to determine its species. Fig. 4 illustrates the potential to discriminate different leptoquark species by measuring parity violating spin asymmetries at $\sqrt{s} = 380$ GeV, which is about the maximum electron proton centre-of-mass energy that could be eventually reached at HERA.

3.6 Fixed target programme at HERA–$\vec{\mathrm{N}}$

In addition to the physics programme at the polarized ep collider, it would be possible to study polarized proton-nucleon collisions at a fixed target experiment in the polarized HERA proton



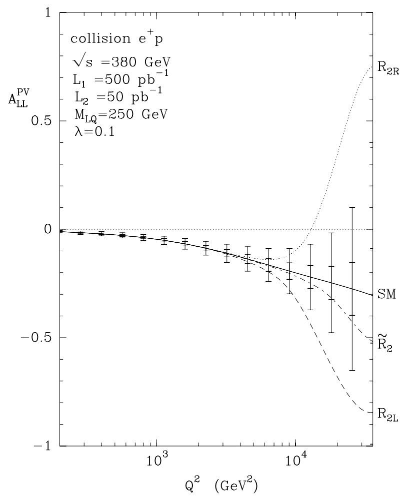


Figure 4: Spin asymmetries in leptoquark production. The different leptoquark species would yield identical effects in unpolarized scattering. See [48] for details.

beam. This proposed experiment, HERA–$\vec{\mathrm{N}}$, would require a polarized internal nucleon target and a dedicated new spectrometer. It could add numerous hadron-hadron observables [50] to the HERA spin physics programme. Very interesting results are expected here, which are fully complementary to the RHIC [15] spin physics program. The two main issues are probes of the polarized parton distributions in double spin asymmetries, e.g. in Drell-Yan process or direct photon production and investigations into hadronic single spin asymmetries.

At this workshop, several new investigations for single spin asymmetries at HERA–$\vec{\mathrm{N}}$ were presented: diffractive production of charmed baryons [51] may be used to investigate the spin structure of diffractive interactions, instanton effects could show up in single spin asymmetries [52] and pion production could serve as a probe of spin transfer in peripheral interactions [53].

4 Conclusions and Outlook

A variety of new information on the spin structure of the nucleon can be expected over the next few years from the continuation of the HERMES experiment and from COMPASS and RHIC, which are currently under construction. These experiments will jointly provide the first data on the gluon polarization in the nucleon from several complementary observables, and supply new information on the quark contribution to the nucleon spin. Despite this wealth of new data to be expected, many questions in spin physics will still remain open. All experiments are limited in their kinematical reach, in particular for the determination of the gluon contribution to the proton spin. Moreover, none of these experiments is sensitive on the structure of the polarized photon - which is completely unknown at present, but of high importance for precision predictions of observables to be studied at future electron-photon or photon-photon colliders.

Polarization of the HERA proton beam would allow the study of polarized electron-proton and photon-proton collisions at high energies, which would allow to measure several aspects of spin structure of proton and photon which are inaccessible elsewhere. Table 1 summarizes the information on polarized parton distributions in the nucleon that can be gained from present and future experiments. The first block summarizes the current status, the second block lists the new reactions that can be probed at ongoing and currently constructed experiments, while the last block illustrates the improvements that could be made at a polarized HERA collider.

At this workshop, new results on the measurability of these key observables were presented: systematic uncertainties in the extraction of the structure function $g_1(x, Q^2)$ from asymmetry measurements are now better understood, next-to-leading order QCD corrections are included in the extraction of the gluon distribution from dijet production and the impact of including charged current HERA data in global fits has been demonstrated. Concerning the study of polarized photon structure at HERA, progress has been made with the introduction of an effective parton approximation, facilitating the extraction of parton distributions from measured asymmetries.

The measurability of several new and potentially interesting observables has been demonstrated at this workshop: spin asymmetries in deep inelastic diffraction could probe the perturbative nature of the diffractive exchange, asymmetries in deeply virtual compton scattering might yield new insights into the proton structure and parity violating asymmetries could prove to be a valuable tool to study possible effects of new physics at HERA.

A new aspect of spin physics at HERA is the possibility of colliding the polarized electron beam of a future linear collider with the polarized HERA proton beam. First studies on the physics prospects of this option were presented at the workshop, and work in this direction is ongoing. Given that the full potential of the linear collider itself can only be exploited if information on the polarized photon structure is available from other sources, this option highlights the complementarity of spin physics at HERA with other future projects at DESY.

Process/ Experiment	**Leading order subprocess**	**Parton behaviour probed**
DIS ($\boldsymbol{\ell N \to \ell X}$) $g_1^{\ell p}, g_1^{\ell d}, g_1^{\ell n}$ (SLAC, EMC/SMC, HERMES)	$\gamma^* q \to q$	Two structure functions $\to$ $\sum_q e_q^2(\Delta q + \Delta\bar{q})$ $\Delta A_3 = \Delta u + \Delta\bar{u} - \Delta d - \Delta\bar{d}$
$\boldsymbol{\ell p, \ell n \to \ell \pi X}$ (SMC,HERMES)	$\gamma^* q \to q$ with $q = u, d, \bar{u}, \bar{d}$	Δu_V, Δd_V, $\Delta\bar{q}$
$\boldsymbol{\ell N \to h^+ h^- X}$ (HERMES,COMPASS)	$\gamma g \to q\bar{q}$ $\gamma q \to qg$	Δg ($x \approx 0.15, 0.1$)
$\boldsymbol{\ell N \to c\bar{c} X}$ (COMPASS)	$\gamma g \to c\bar{c}$	Δg ($x \approx 0.15$)
$\boldsymbol{pp \to (\gamma^*, W^\pm, Z^0) X}$ (RHIC)	$q\bar{q} \to \gamma^*, W^\pm, Z^0$	Δu, $\Delta\bar{u}$, Δd, $\Delta\bar{d}$ ($x \gtrsim 0.06$)
$\boldsymbol{pp \to}$ **jets** $\boldsymbol{X}$ (RHIC)	$q\bar{q}, qq, qg, gg \to 2j$	Δg (?) (x $\gtrsim$ 0.03)
$\boldsymbol{pp \to \gamma X}$ (RHIC)	$qg \to q\gamma$ $q\bar{q} \to g\gamma$	Δg (x $\gtrsim$ 0.03)
DIS ($\boldsymbol{e^\pm p \to \nu X}$) $g_1^\pm, g_5^\pm$ (HERA)	$W^* q \to q'$	Two structure functions $\to$ $\Delta u - \Delta\bar{d} - \Delta\bar{s}$ $\Delta d + \Delta s - \Delta\bar{u}$
DIS (small x) g_1^{ep} (HERA)	$\gamma^* q \to q$	$\alpha_{q,g}$ ($\Delta\bar{q} \sim x^{\alpha_q}, \Delta g \sim x^{\alpha_g}$)
$\boldsymbol{\ell N \to \ell}$ **jets** $\boldsymbol{X}$ (HERA)	$\gamma^\star g \to q\bar{q}$ $\gamma^\star q \to qg$	Δg ($x \gtrsim 0.003$)
$\boldsymbol{pp \to \ell^+ \ell^- X}$ (HERA-$\vec{\mathrm{N}}$)	$q\bar{q} \to \gamma^\star$	$\Delta\bar{q}$ ($x \gtrsim 0.15$)

Table 1: Information on polarized parton distributions from present and future experiments.

References

[1] J. Feltesse and A. Schäfer, Proceedings of the workshop "Future Physics at HERA", Hamburg 1995/96, eds. G. Ingelman, A. De Roeck and R. Klanner, DESY (Hamburg, 1996), p.757ff.

[2] A. De Roeck and T. Gehrmann (eds.), Proceedings of the Workshop "Physics with Polarized Protons at HERA", DESY, March - September 1997, DESY–Proceedings 98-001.

[3] A. Deshpande, these proceedings (hep-ex/9908051).

[4] HERMES collaboration, K. Ackerstaff et al., preprint DESY-99-048 (hep-ex/9906035).

[5] HERMES collaboration, A. Airapetian et al., preprint DESY-99-071 (hep-ex/9907020).

[6] A. Bravar, D. von Harrach and A. Kotzinian, Phys. Lett. **B421** (1998) 349.

[7] O. Teryaev, these proceedings.

[8] M. Anselmino, M. Boglione and F. Murgia, these proceedings (hep-ph/9907269).

[9] A.V. Efremov, O.G. Smirnova and L.G. Tkatchev, these proceedings.

[10] Z.E. Meziani, talk given at this workshop.

[11] J. Blümlein, these proceedings (hep-ph/9907543).

[12] G. Schierholz et al., these proceedings.

[13] J. Soffer and O. Teryaev, these proceedings (hep-ph/9906455).

[14] F. Kunne, these proceedings.

[15] G. Bunce, these proceedings.

[16] O. Martin and A. Schäfer, these proceedings.

[17] J. Sowinski, these proceedings.

[18] E.W.N. Glover and A.G. Morgan, Z. Phys. **C60** (1993) 175.

[19] S. Frixione, Phys. Lett. **B429** (1998) 369.

[20] S. Frixione and W. Vogelsang, preprint hep-ph/9908387.

[21] A. Chao, these proceedings.

[22] A. De Roeck et al., Eur. Phys. J. **C6** (1999) 121.

[23] C. Aidala, A. Deshpande and V.W. Hughes, these proceedings.

[24] J. Lichtenstadt, these proceedings.

[25] A. Deshpande, these proceedings.

[26] SMC collaboration, B. Adeva et al., Phys. Rev. **D** (in press, preprint CERN-EP-99-061).

[27] S. Bass and A. De Roeck, these proceedings;
M. Goshtasbpour and P.G. Ratcliffe, these proceedings;
S.M. Troshin and N.E. Tyurin, these proceedings (hep-ph/9905564).

[28] B. Badelek, J. Kiryluk and J. Kwieciński, preprint hep-ph/9907569.

[29] J. Bartels, B.I. Ermolaev and M.G. Ryskin, Z. Phys. **C70** (1996) 273; **C72** (1996) 627.

[30] J. Kwieciński and B. Ziaja, these proceedings and preprint hep-ph/9902440.

[31] J. Bartels and M.G. Ryskin, these proceedings.

[32] S. Manaenkov, these proceedings and preprint hep-ph/9903405.

[33] J. Bartels, T. Gehrmann and M.G. Ryskin, these proceedings and Eur. Phys. J. **C** (in press, preprint hep-ph/9906204).

[34] S. Goloskokov, these proceedings (hep-ph/9907429).

[35] G. Rädel, A. De Roeck and M. Maul in [2], p.77.

[36] G. Rädel and A. De Roeck, these proceedings.

[37] E. Mirkes and S. Willfahrt in [2], p.69.

[38] I. Akushevich and S. Chekanov, these proceedings.

[39] J. Kwieciński and B. Ziaja, these proceedings and preprint hep-ph/9906499.

[40] J.M. Butterworth, N. Goodman, M. Stratmann and W. Vogelsang in [2], p.120.

[41] D. de Florian and S. Frixione, Phys. Lett. **B457** (1999) 236.

[42] B.L. Combridge and C.J. Maxwell, Phys. Lett. **B239** (1984) 429.

[43] M. Stratmann and W. Vogelsang, these proceedings (hep-ph/9907470).

[44] T. Morii and K. Sudoh, these proceedings.

[45] Yu. Arestov, these proceedings.

[46] X. Ji, Phys. Rev. **D55** (1997) 7114;
A.V. Radyushkin, Phys. Rev. **D56** (1997) 5524.

[47] A. Freund and M. Strikman, these proceedings.

[48] A. De Roeck, P. Taxil, E. Tugcu and J.M. Virey, these proceedings.

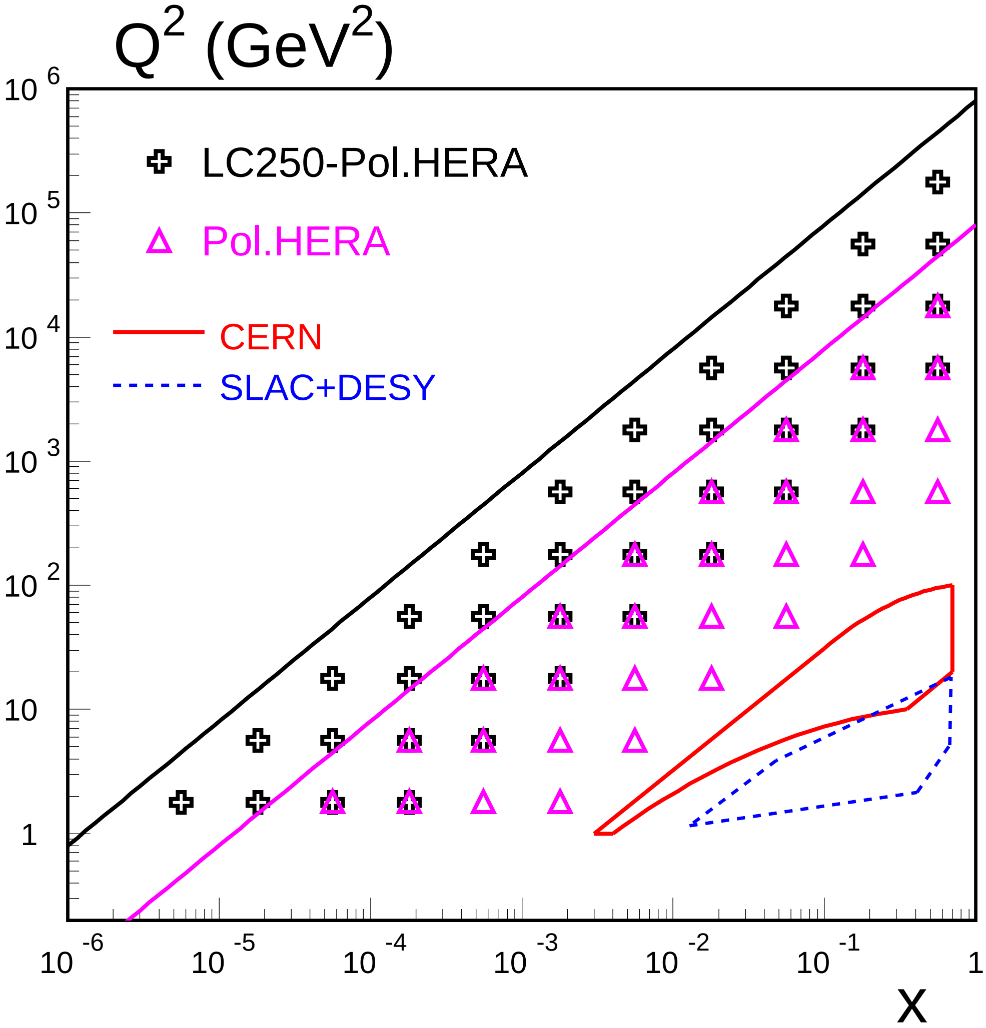
[49] W. Buchmüller, R. Rückl and D. Wyler, Phys. Lett. **B191** (1987) 442.

[50] V.A. Korotkov and W.D. Nowak, these proceedings (hep-ph/9908490).

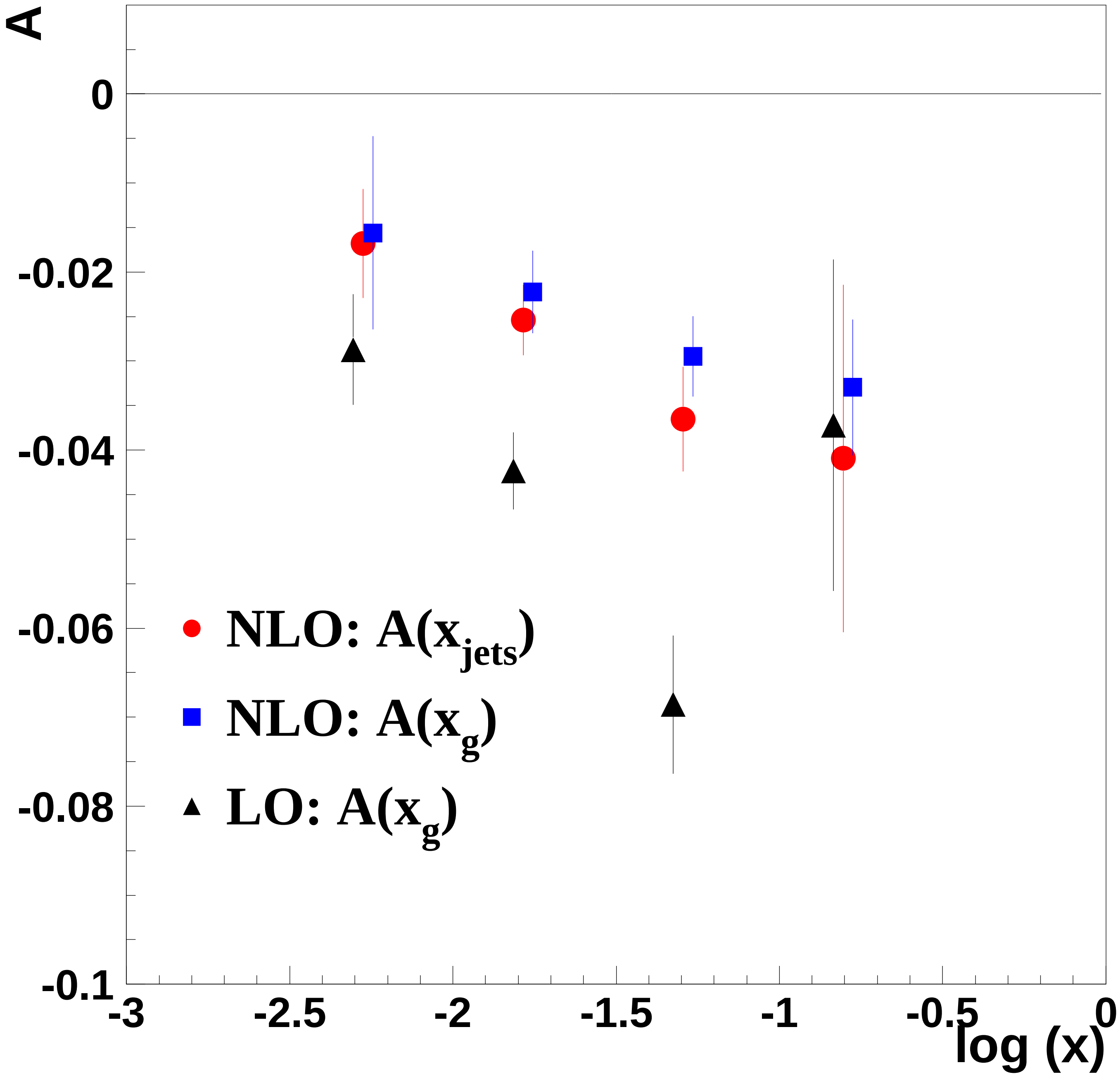
[51] N. Kochelev, T. Morii and S. Oyama, these proceedings.

[52] N. Kochelev, these proceedings (hep-ph/9905497).

[53] A. Akhmedov, I. Akushevich, E. Kuraev and P. Ratcliffe, these proceedings and preprint hep-ph/9902418.



Q2 (GeV2)
LC250-Pol.HERA
Pol.HERA
CERN
SLAC+DESY
10 6
10 5
10 4
10 3
10 2
10
1
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
x


A
0
-0.02
-0.04
-0.06
-0.08
-0.1
-3
-2.5
-2
-1.5
-1
-0.5
0
log (x)
NLO: A(x_jets)
NLO: A(x_g)
LO: A(x_g)